Atmosphere and coastal ocean CO_2 measurement platform - SABSOON

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Year 1 Progress Report

Summary

A prototype system to measure atmospheric CO_2 to an accuracy of 0.1 ppm over the ocean has been designed and built and is now being tested on the RVIB LM Gould. The results of an inter-calibration of this system with NOAA/CMDL flasks done at the end of March 2005 will confirm the success of our system in measurement environments similar to those which we expect on the ship. In this report we show preliminary results of our efforts to passively control expected temperature fluctuations as well as a new set up for controlling flow of standards and atmospheric gas sample flow rates. A slight delay in support for the first 5 months of the first year in this project slightly mitigated the development stage of this project. We have now caught up. In order to validate the success of this project at a lower cost, the .1 ppm system will be set up for testing on the Martha's Vineyard Tower site which will allow for easier access to power, communications and instrumentation to diagnose the new developments to our pCO_2 system. We are now working with engineers and scientists who maintain and perform science at the SABSOON site and we will be transitioning the advanced system to the South Atlantic Bight (SAB) over the next year. This work will be in concert with the CMDL automated flask monitoring system.

Objectives

The objectives of this project are to:

- Measure the pCO_2 in the atmosphere and ocean at South Atlantic Bight Synoptic Offshore Observational Network (SABSOON). High-resolution Non-Dispersive InfraRed NDIR detection of CO_2 will be compared to flask measurements.
- Determine ΔpCO_2 at the tower using the high-resolution IR technique in order to estimate the coastal air-sea CO_2 flux variability.
- Quantify and describe the temporal variability in atmosphere and ocean CO_2 concentrations.

- Determine the relative importance of biological and physical controls on CO_2 concentrations and air-sea CO_2 exchange at a coastal site.

- Determine the influence of coastal ocean carbon on the North American terrestrial carbon cycling.

Required New Developments to Achieve Objectives:

The stated objectives of this project require development of the following:

- Autonomous infrared measurements of atmospheric CO_2 will be designed:
  - To have a measurements accuracy of 0.1 ppm.
  - To operate for up to 2 months without any direct on-sight intervention
  - To control all temperature fluctuations in the NDIR cell passively (to conserve amount of power required for instrument operation) to less than 1 C hr^{-1}.
  - Air-flow control system that can handle heavy aerosol load expected in tower environment with minimum amount of dead volume.
  - Long term air drying system
- Autonomous measurements of seawater CO_2 from tower include:
  - The development equilibrator system which can handle big wave action but does not require pumping of seawater greater than 1 meter above mean high water.

Development progress:

1) Autonomous infrared measurements of atmospheric CO_2 have been designed and include:
   a. Air flow control system
      i. Because of the large temperature variations and large aerosol load flow of gases through IR detector is very hard to control in conditions that we expect on the tower over the long term. Previous attempts to use off the shelf flow controller have been problematic due to dead space problems and aerosol fowling. In an attempt to rectify this problem we have developed a stepper motor controlled pin valve system which seems to give us very nice flow control over a variety of pressure regimes (Fig 1).

   b. Passive control of IR cell temperature
      i. A key to achieving measurement accuracy at the 0.1 ppm level is control of incoming gas and IR detector cell temperature. While this can be achieved using active temperature control we are interested in doing this passively to reduce the power consumption. We are doing this by creating a heat sink made from seawater stored in a 150 L barrel. Air is pumped through tubing in the barrel and into an insulated box containing the IR detector. The results of the initial design show that temperature change can be controlled to within 1 C /hr which on a normal day that might vary in temperature as much 20 C. While we would like to reduce the

temperature change to 0.1 C/hr, the results shown here indicate a very linear change in IR cell temperature despite non linear changes in outside temperature. This suggests that drift corrects with hourly standard analysis will be sufficient to account for temperature changes.

c. Remote operation
    i. In an effort not to lose time we have decided to perform the deployment on the SABSOON tower after testing in similar conditions on the Martha's Vineyard Tower and the RV LM Gould. With the new air-flow control system installed on our RV LM Gould we are presently in the process of testing how robust the system will be in the long term.

d. 0.1 ppm accuracy test
    i. In addition to testing the flow controlled system on the RV LM Gould we will also be doing an inter-calibration exercise with NOAA/CMDL flask sample in the end of March during a Drake Passage crossing to test the accuracy of our measurements.

e. Long term air drying system
    i. A system for drying air which uses a combination of Naphion and a chemical dryer similar to those used on land- based Tall Towers has been built and is being tested on the Martha's Vineyard Towers. No conclusive results have been found at the time that this report was prepared.

2) Autonomous measurements of seawater CO_2 from tower
    a. Develop equilibrator system
        i. The major challenge to measuring seawater from towers is choosing a robust system for equilibrating seawater with an air stream that can be measured with infrared analyzers. Because towers are not free floating positioning the equilibration system on a stable platform requires excessive power to pump water to heights that we anticipate putting the IR system at. To reduce power requirements we are testing a system on the Martha's Vineyard Tower which is small and compact enough to be mounted separately on the leg of the tower about 2 meters above mean water height.

Fig 1. Prototype atmospheric and ocean pCO_2 system for SABSOON tower. This system features a standard/sample gas flow control system controlled by stepper motor (red) and pin valve in a feedback loop with Gas flow meter. Picture shows prototype installed on RVIB LM Gould where inter-calibration with NOAA/CMDL Flasks will take place.

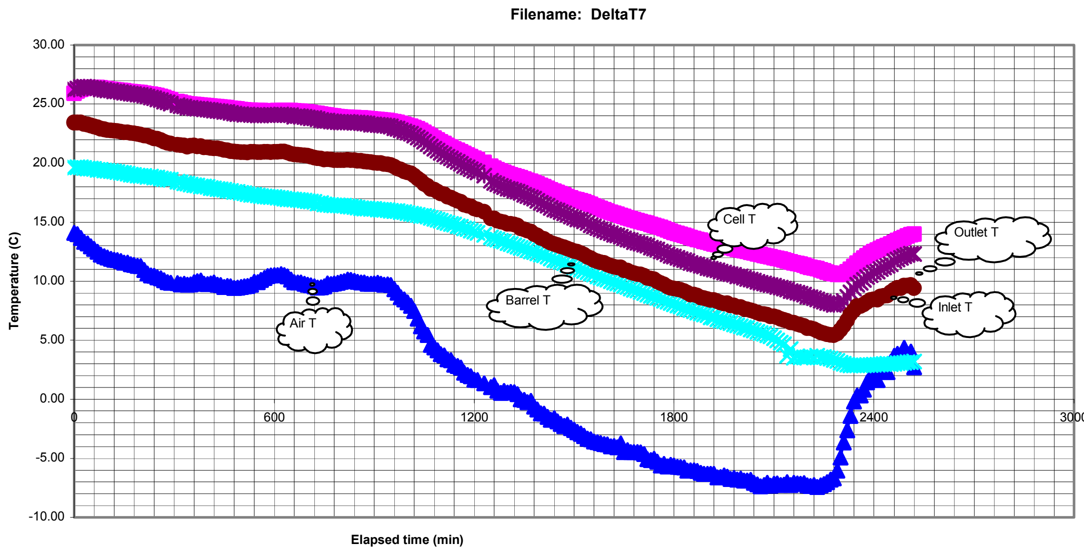

Fig 2. Temperature control tests. Magenta line shows cell temperature. Purple and brown lines show outlet and inlet line of air flowing from insulated infrared analyzer box to water barrel. Light blue line shows water barrel temperature and dark blue shows outside temperature. Results show that outside temperature changes are reflected in very linear temperature changes inside the analyzer box indicating that drift correction made from hourly sampling will be sufficient to account for most of the variability outside temperature on tower system.

Summary

The first-term goals of this project have been worked on over the past year. Our goal is the best-performing atmospheric pCO_2 system designed which consumes low power, is autonomous, and complements the atmospheric flask network over the marine boundary layer. This is a necessary measurement to increase the accuracy of the terrestrial NACP atmospheric inversion measurements. This is exciting for both ocean carbon and terra carbon science. We will also be measuring the air-sea pCO_2 difference to understand the physical and biogeochemical controls of oceanic carbon in the coastal ocean. The next phase of deployment will be two-pronged: [1] deployment at the MVO for easy access and [2] working with SABSOON scientists and engineers for deployment. We hope to eventually have these high-resolution, accurate atmospheric and oceanic pCO2 systems running in the MAB, SAB, and at several coastal sites in between.